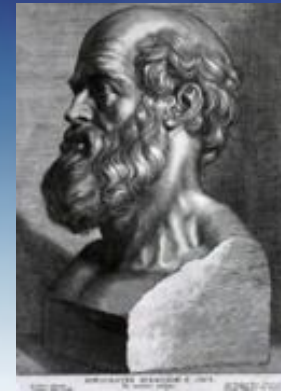


Data to Insights and Actions: Enabling Evidence-Based Healthcare

Eric Horvitz
Microsoft Research

NITRD Symposium
Washington DC
February 2012

A Long-Term Pursuit



Hippocrates (c. 460 B.C. - c. 370 B.C.)

- On diseases, make a habit of two things—to help, or at least to do no harm.

Epidemics, in Hippocrates, trans. W. H. S. Jones (1923), Vol. I, 165.

- ...it is worth learning from everyone; for people do not discover these by reasoning but by chance, and experts not more than laymen.

Affections, in Hippocrates, trans. P. Potter (1988), Vol. 5, 69. Littré VI, 254.

*Attaining dream of evidence-based reasoning
through advances in computer science.*

Fueling Pursuit of the Dream

Significant advances made possible via long-term funding by prescient federal agencies

- Critical NIH, NSF, ONR, DARPA support for decades
- AI in Medicine (AIM) in 1980s → Core CS
 - Ignited veritable revolution in machine intelligence
 - Core advances in context of AIM:
representation, inference, decision making, machine learning for medical applications.



Exciting Times

- ↑ **Learning & reasoning prowess**
- ↑ **Sensing, interaction, ubiquity**
- ↑ **Computation & connectivity**
- ↑ **Data capture → learning, decisions**

Wrestling with a Bottleneck

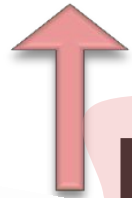
- ↑ Learning & reasoning prowess
- ↑ Sensing, interaction, ubiquity
- ↑ Computation & connectivity
- ↑ Data capture → learning, decisions



Enabling Evidence-Based Medicine

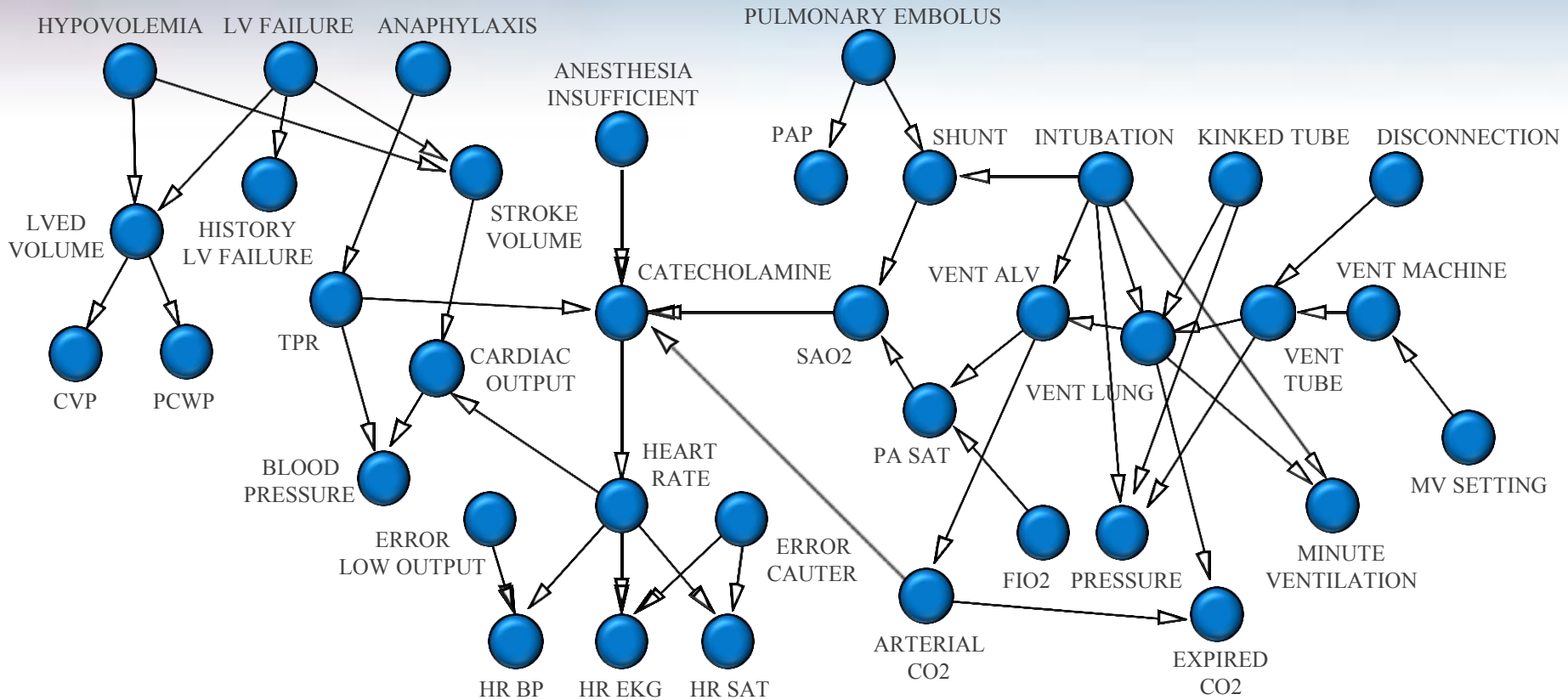
- **Diagnosis, actions, policies**
- **Wellness and prevention**
- **Discovery**

Data capture → **learning, decisions**



Advances in Representation & Reasoning

- e.g., Probabilistic graphical models



(From I. Beinlich, et al)

Expert Knowledge in Decision Support

The screenshot shows a web browser window titled "Microsoft Pregnancy and Child Care". The browser's address bar contains "Home", "Go To", "Find", "Options", and "Help". The main content area features a light blue background with a large graphic of two hands, one green and one yellow, reaching towards each other. On the right side, there is a navigation menu with five items, each preceded by a red arrow icon. The top right corner displays the "Medical Advisory Board" logo, which consists of a caduceus symbol inside a circle.

Microsoft Pregnancy and Child Care

Home Go To Find Options Help

Microsoft Health Preview

Pregnancy and Child Care

Medical Advisory Board

- **What's New**
Click here for this month's highlights in Microsoft Pregnancy and Child Care.
- **Library**
To browse through illustrated articles on pregnancy, birth, and early child care, click here.
- **Find By Word**
If you know what you're looking for, click here to search the Library by keywords.
- **Find By Symptom**
Click here to find useful information in the Library related to children's symptoms.
- **Community Center**
Have a story to share? Want to send us mail? Click here to access our community bulletin boards.

Expert Knowledge in Decision Support

Describe the child

in the drop-down boxes at the right. Relevant information will appear below.

Age: Sex:

Complaint:

Localized pain: Can the child localize, or point to, the site of the pain?

- No, unable to localize
- Below the navel to the child's left
- Above the child's navel
- Either of the child's sides
- Below the navel to the child's right
- Above the navel to the child's right
- Above the navel to the child's left
- Don't Know

Start Over

Review

Next>>

Finish

Results so far

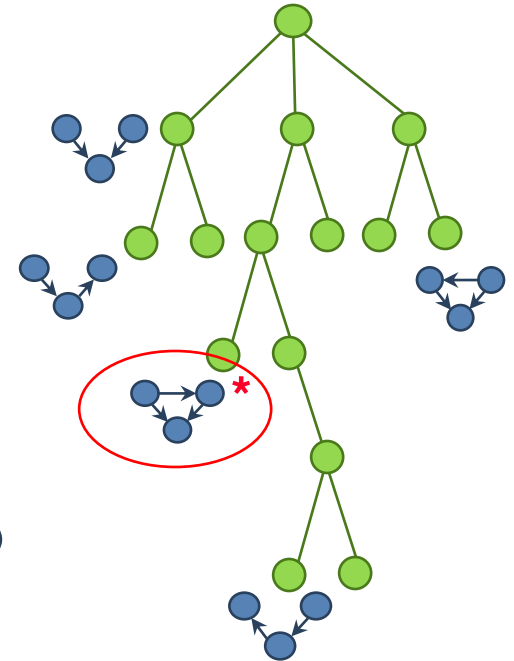
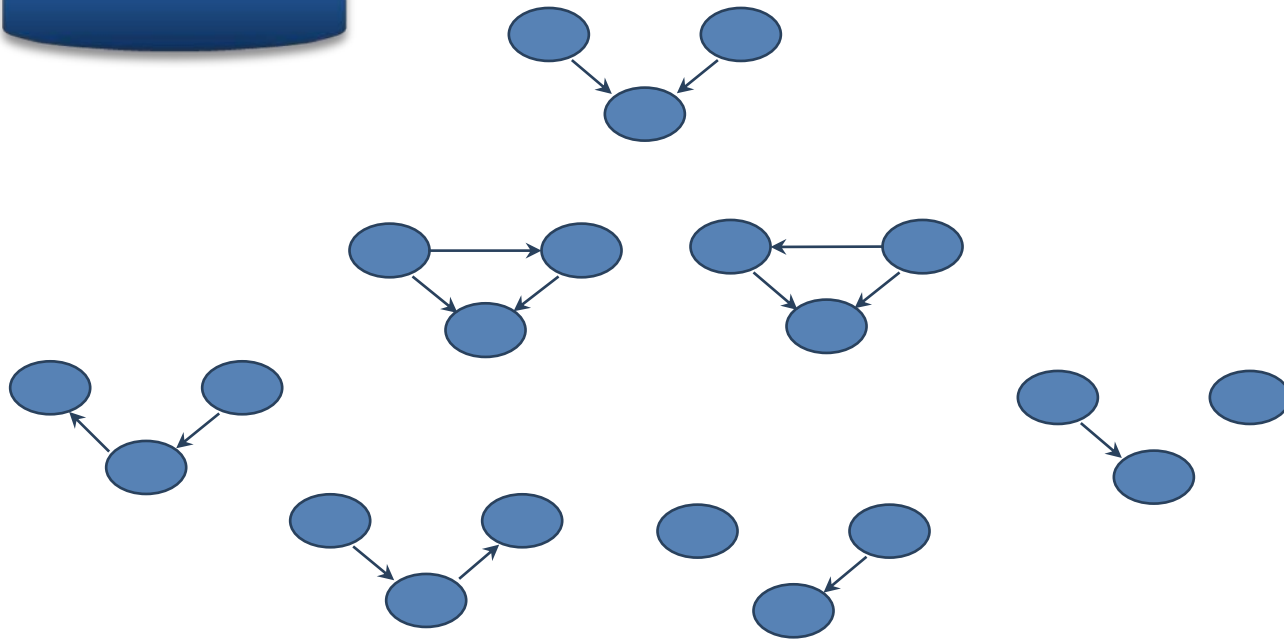
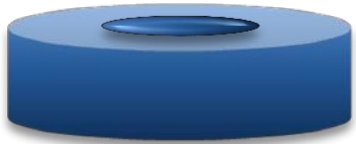
Disorder

Relevance

Viral gastroenteritis	
Psychosomatic pain	
Urinary tract infection	
Other	

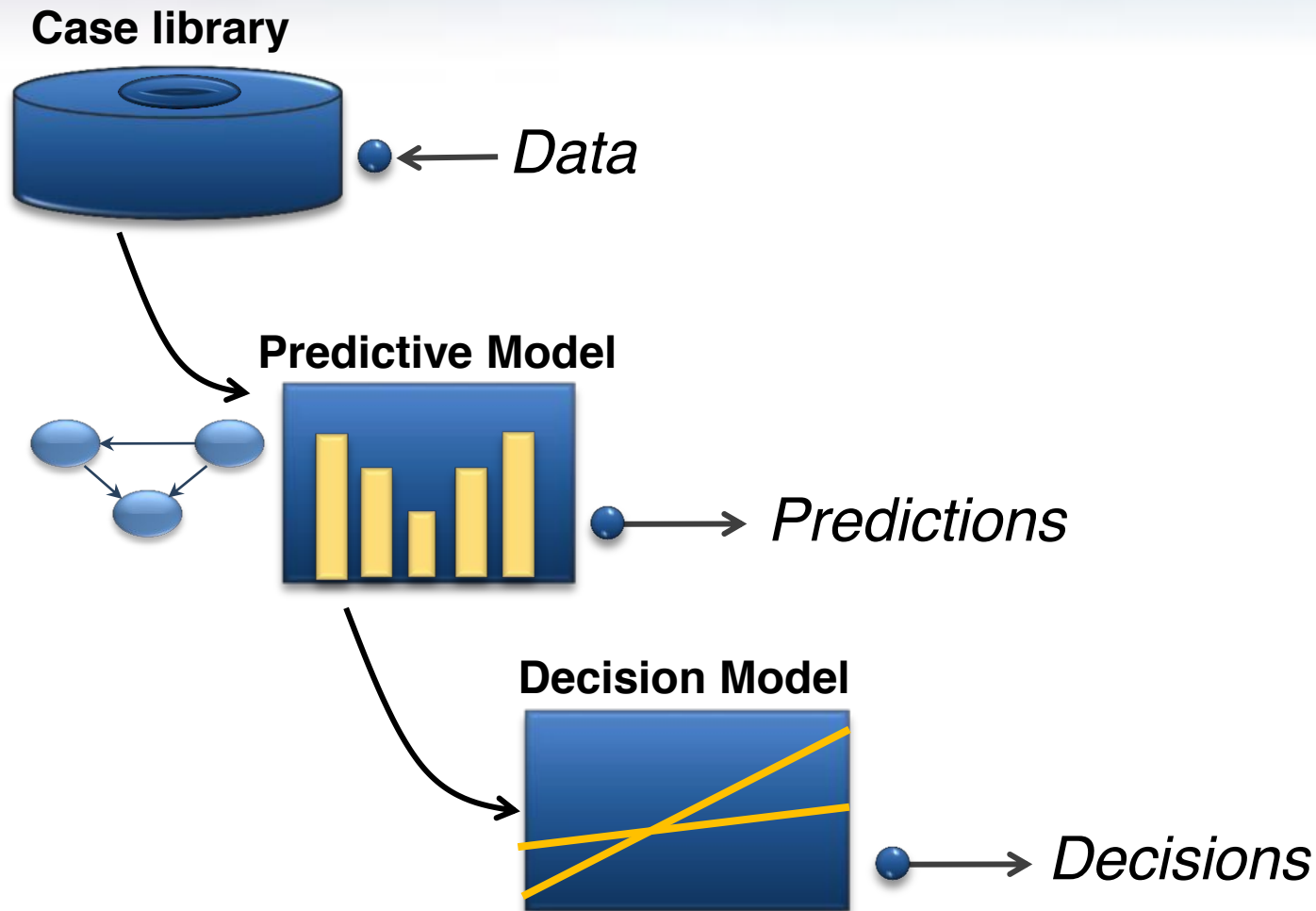
Learning Predictive Models from Data

- New access to large amounts of data
- Procedures for learning predictive models



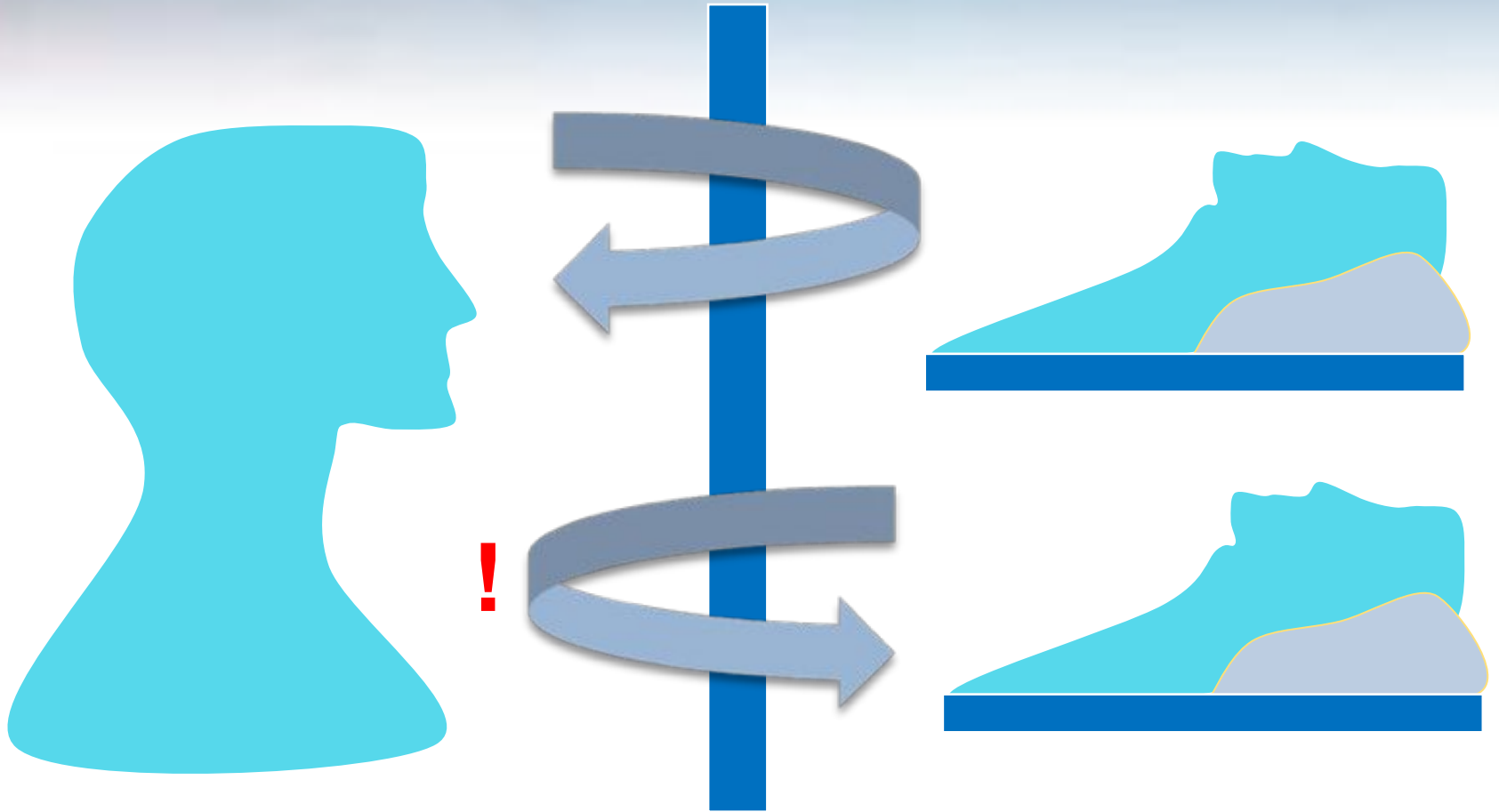
Data → Prediction → Decisions

- Best actions via analysis of costs & benefits under uncertainty



Example:

Reducing Hospital Readmissions



Costly Challenge



THE NEW ENGLAND
JOURNAL of MEDICINE

SPECIAL ARTICLE

2005

Volume 353 (14): 1428-1438

April 1, 2005

Number 14

1427

Rehospitalizations among Patients in the Medicare Fee-for-Service Program

Stephen F. Jenike, M.D., M.P.H., Mark F. Williams, M.D., and Eric A. Coleman, M.D., M.P.H.

ABSTRACT

Background: Rising rates of rehospitalization have attracted attention from policymakers and a need to improve the quality of care. We examined the frequency and cost of rehospitalizations among Medicare Fee-for-Service patients to aid in planning the necessary changes.

Methods: We analyzed

- ~20% within 30 days
- ~35% in 90 days
- ***Estimated cost to Medicare in 2004: \$17.4 billion***

Learning from a Case Library

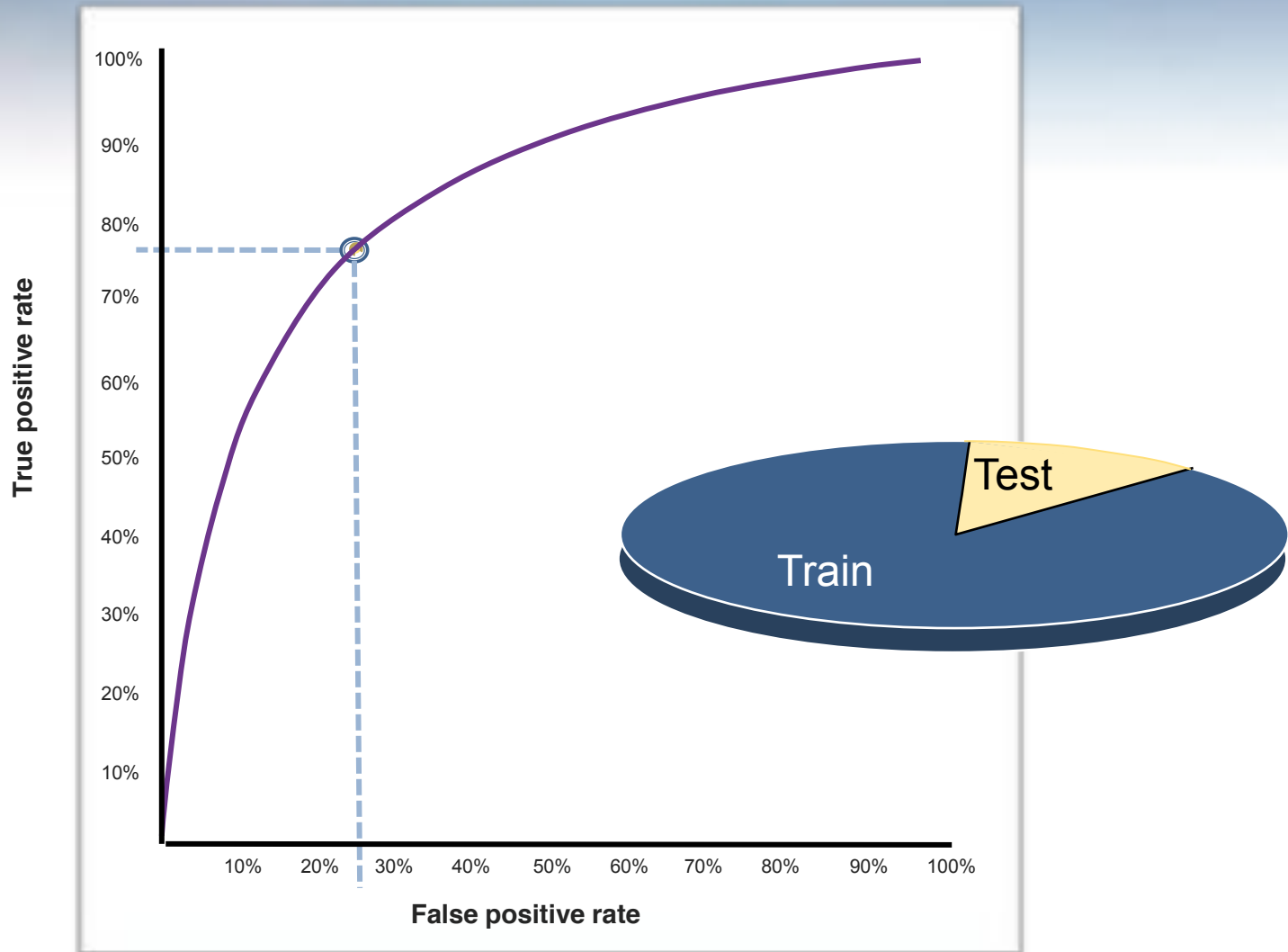
- Washington Hospital Center hospital system (DC)
- All visits during the years 2001 to 2009 (e.g., ~300,000 ED visits)
 - Admissions, discharge, transfer (ADT)
 - Chief complaint in free text
 - Age, gender, demographics
 - Diagnosis codes (ICD-9)
 - Lab results and studies
 - Medications
 - Vital signs
 - Procedures
 - Locations in hospital
 - Admitting and attending MD codes
 - Fees and billing

~25,000 variables considered in dataset

Building a Predictive Model for Readmission



Performance of Classifier for Readmission



Identifying Evidential Relevance

Weight	Feature description	Frequency
0.68398	Dx0->2 = Excessive vomiting in pregnancy	0.31%
0.61306	Dx3->2 = Personal history of malignant neoplasm	0.28%
0.58281	Dx0->2 = Heart failure	0.30%
0.56708	Dx0->1 = Nephritis, nephrotic syndrome, and nephrosis	0.09%
0.56649	Dx3->2 = Heart failure	0.28%
0.54663	Complaint sentence contains "suicidal"	0.17%
0.48415	Dx1->2 = Disorders of function of stomach	0.07%
0.47257	Dx5->0 = Diseases Of The Genitourinary System	0.15%
0.46136	Dx0->2 = Chronic airway obstruction, not elsewhere classified	0.10%
0.44555	Dx4->2 = Depressive disorder, not elsewhere classified	0.10%
0.44257	Stayed 14 hours in the ER	0.10%
0.43890	Dx0->1 = Other psychoses	0.32%
0.43513	Dx0->0 = Diseases Of The Blood And Blood-Forming Organs	0.46%
0.42582	Complaint sentence contains "dialysis"	0.19%
0.41888	Dx0->2 = Depressive disorder, not elsewhere classified	0.27%
0.41302	Dx1->1 = Nephritis, nephrotic syndrome, and nephrosis	0.29%
0.38506	Complaint sentence contains "fluid"	0.10%
0.37474	69 < Age	9.22%

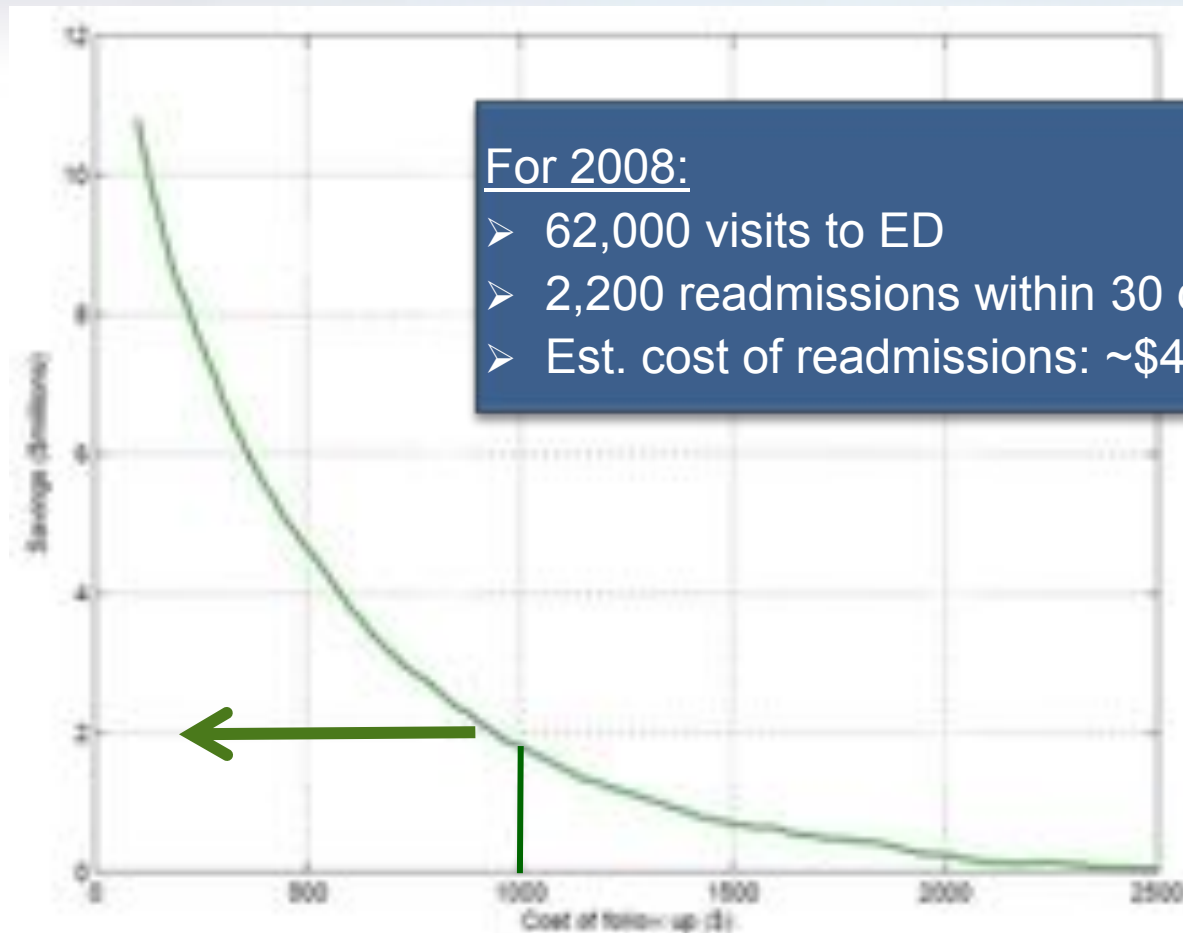
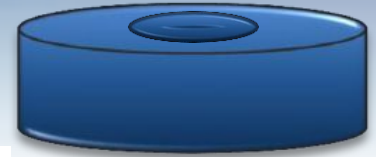
Take Action to Reduce Readmissions?

- Interventions are costly but promise reduced likelihood of readmission
 - Post-discharge care coordination
 - Patient education
 - Scheduled outpatient visits
 - Telemedicine, connected health

Experiences with costs and efficacies reported in literature.

Analysis of Value of Decision System

- Predictive model, 2004-2007, test cases from 2008
- Costs, efficacy from studies

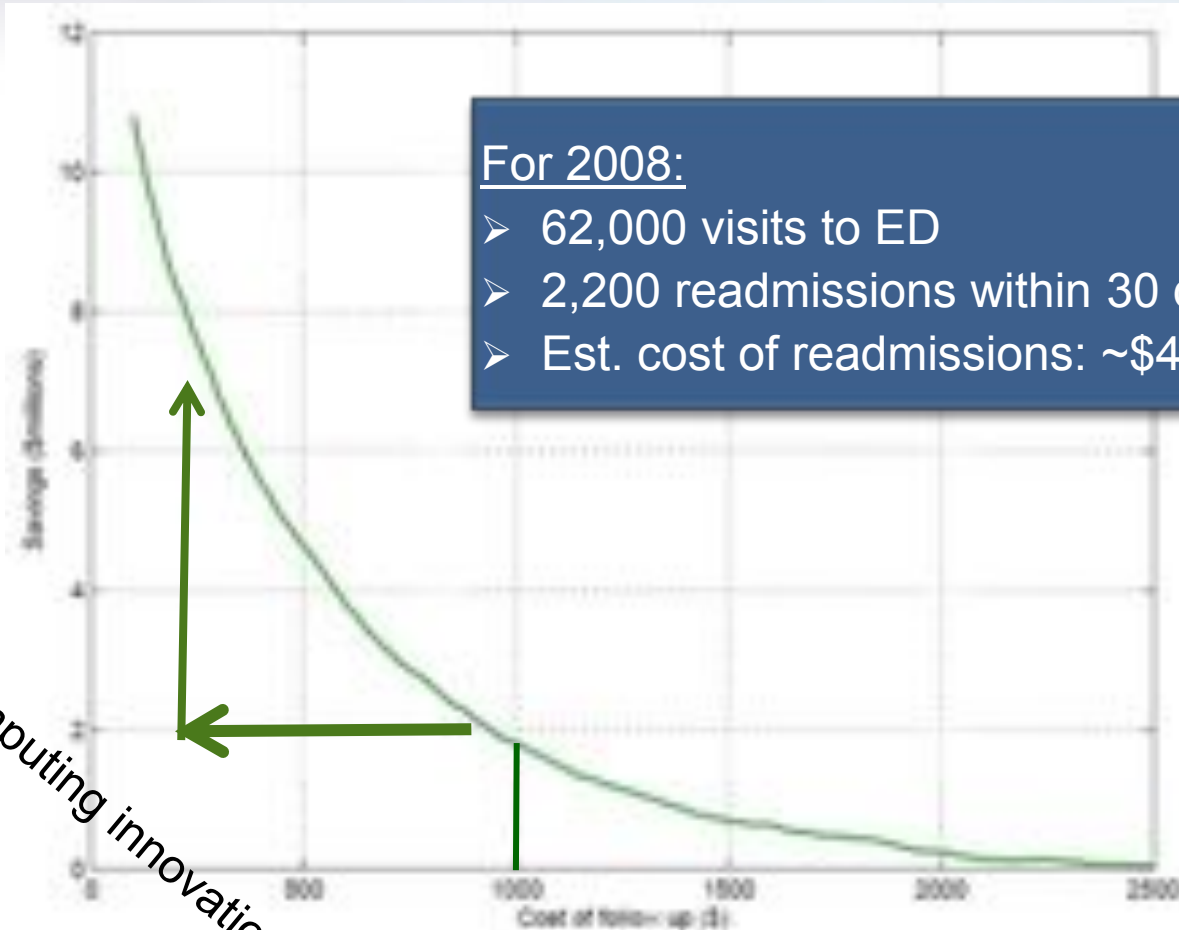
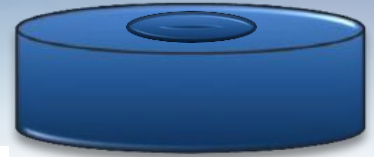


For 2008:

- 62,000 visits to ED
- 2,200 readmissions within 30 days
- Est. cost of readmissions: ~\$44,000,000

Analysis of Value of Decision System

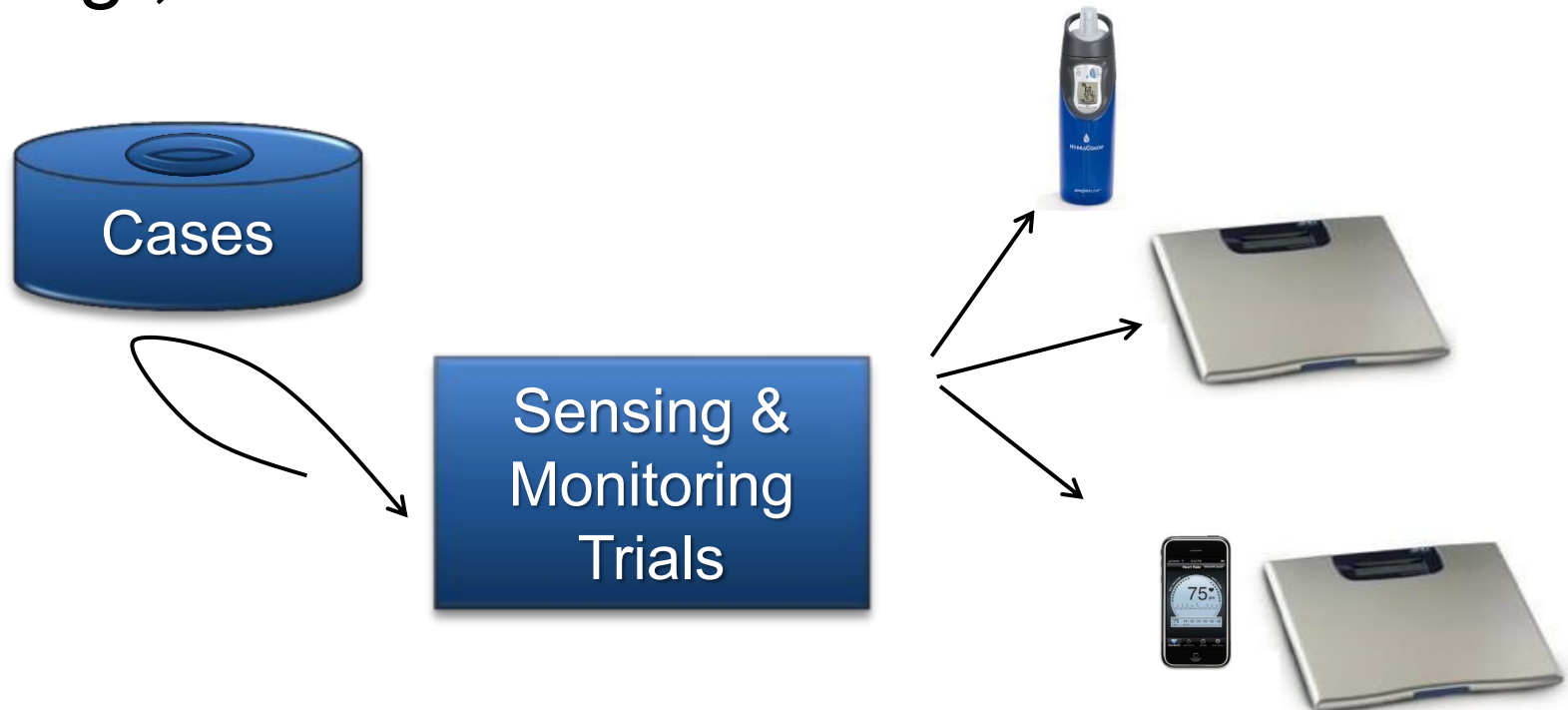
- Predictive model, 2004-2007, test cases from 2008
- Costs, efficacy from studies



Sensing & computing innovations

Toward Site-Specific Trials

- “Clinical trials” of sensing & intervention strategies
- Local learning cycle for hospital centers, e.g., CHF



Translation: Research to Open World

Readmissions Manager for Microsoft Amalga

Reducing Hospital Readmissions is an Impending Priority

Overview

One in five Medicare inpatients is readmitted within 30 days. The Centers for Medicare and Medicaid Services (CMS) considers 40%-75% of these readmissions to be preventable.

In October 2012, CMS will begin to track readmissions and impose financial penalties on hospitals with higher-than-expected readmission rates for certain conditions. Other payers will certainly follow.

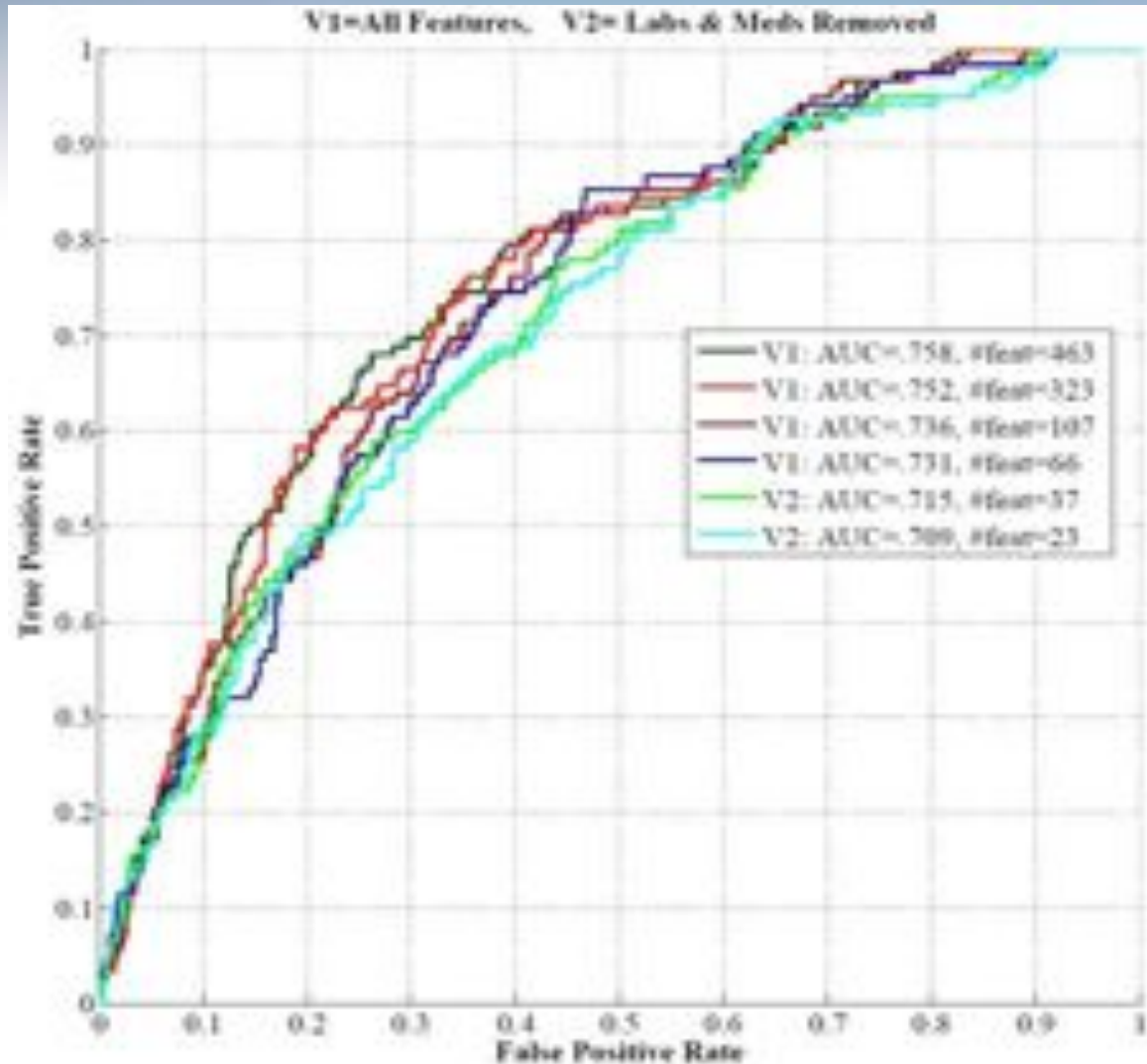
It is clear that hospital admissions and readmissions are becoming a critical parameter for tracking care delivery from both a financial and quality perspective.

Readmissions Manager for Microsoft Amalga is an innovative solution to help organizations address this very important business need.



Readmissions Manager Targets Avoidable Hospital Readmissions

Engineering: Tractability and Tradeoffs



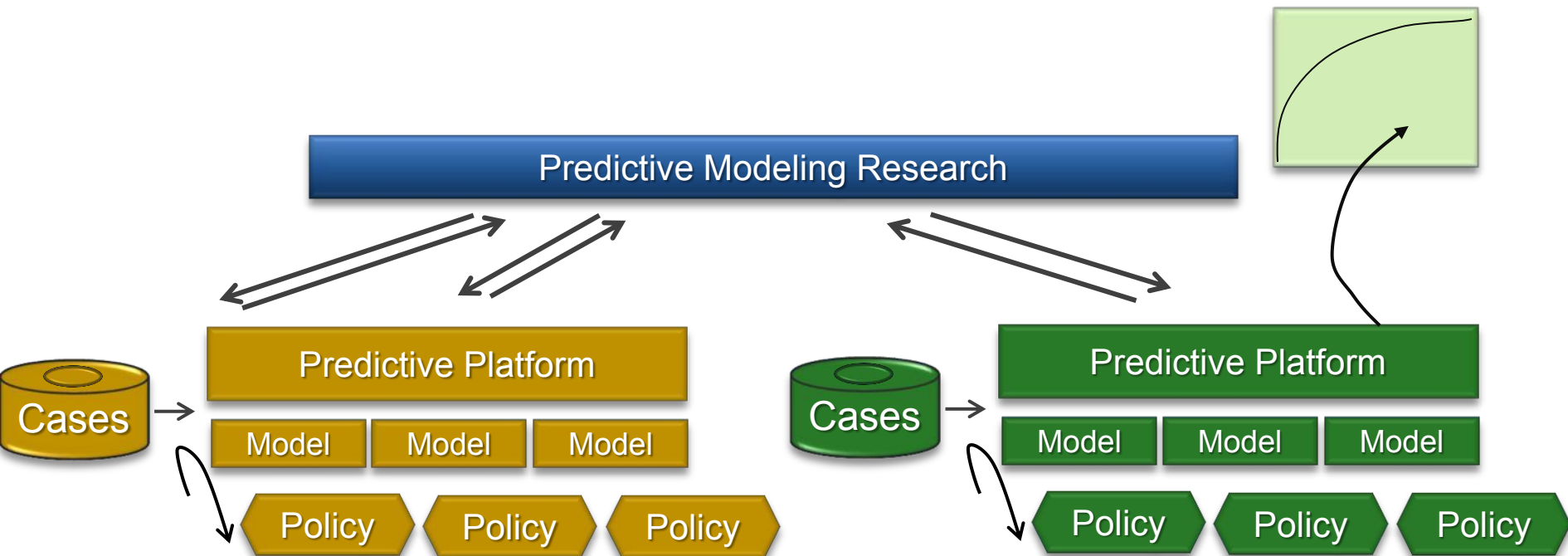
Predictive Platform Goes Live...



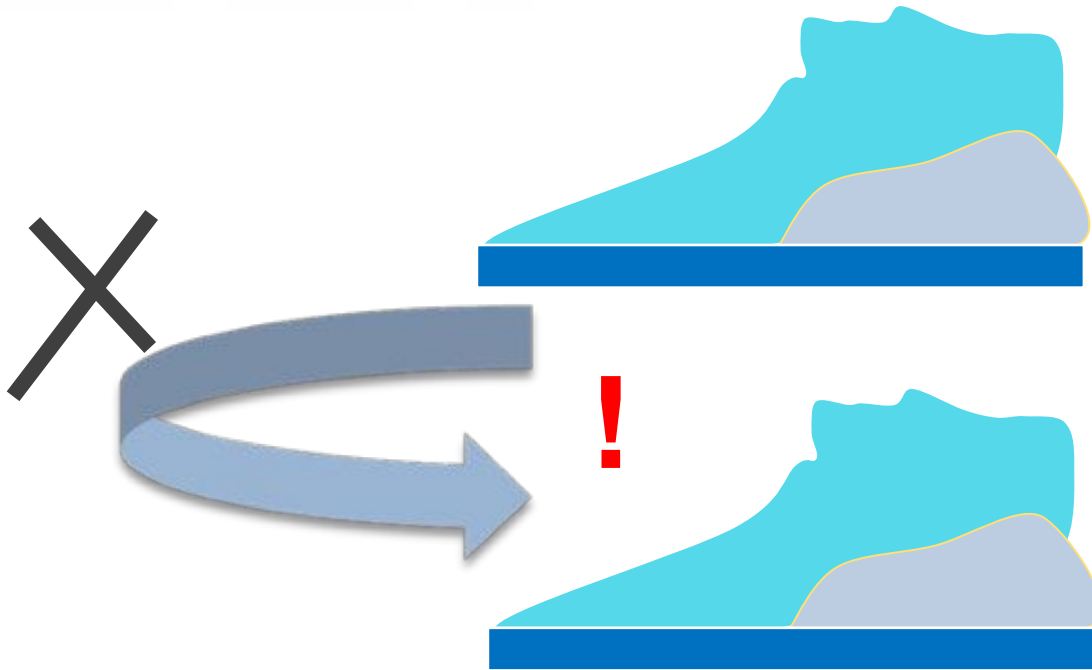
Learning from In-World Application

Automation \longleftrightarrow expert handholding?

- Data differences \rightarrow universal schema
- Local train and test cycle
- Quality assurance



Example: Reducing Medical Errors & Injuries



Challenge of Medical Errors & Injuries

- **Deaths attributed to medical error:**

44,000 - 98,000 / year U.S., preventable errors.

“To Err is Human,” Inst. of Medicine, 2000

- **Adverse medical events:**

13.5% of hosp. Medicare patients, 44% preventable.

Levinson, 2010

- **Costs of errors:**

\$17 to \$29 billion per year in U.S.

Thomas, et al., 1999

Medical Errors & Injuries in the News

The New York Times

Health

WORLD

U.S.

N.Y. / REGION

BUSINESS

TECHNOLOGY

SCIENCE

HEALTH

Report Finds Most Errors at Hospitals Go Unreported

WASHINGTON — Hospital employees recognize and report only one out of seven errors, accidents and other events that harm Medicare patients while they are hospitalized, federal investigators say in a new report.

Yet even after hospitals investigate preventable injuries and infections that have been reported, they rarely change their practices to prevent

repetition of the "adverse events."
Lewenson, inspector general of the
Services.

In the report, being issued on Friday, the inspector general says that a key condition of being paid under Medicare is that hospitals must report "adverse events" and address patient safety.

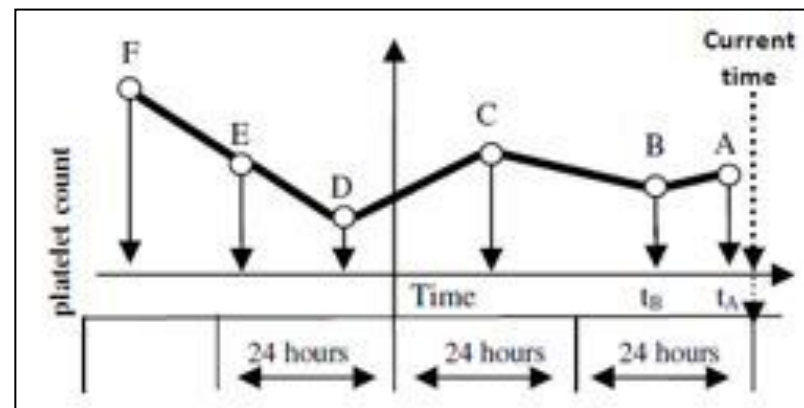
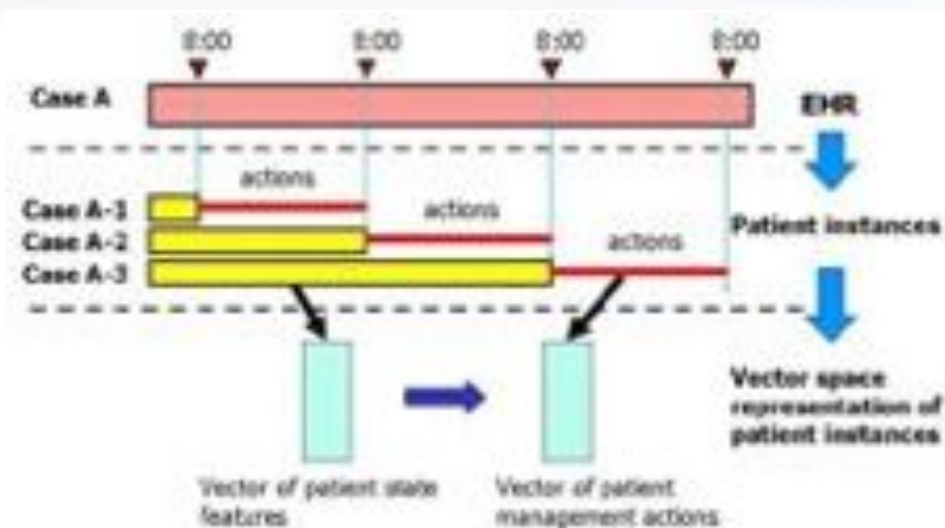
-  Facebook
-  Twitter
-  LinkedIn
-  Print this page
-  Email

CMS Issues Medicare Final Payment Rule; Strengthens Tie Between Payment and Quality Improvement

August 2, 2011

Direction: Learn to Detect Anomalies

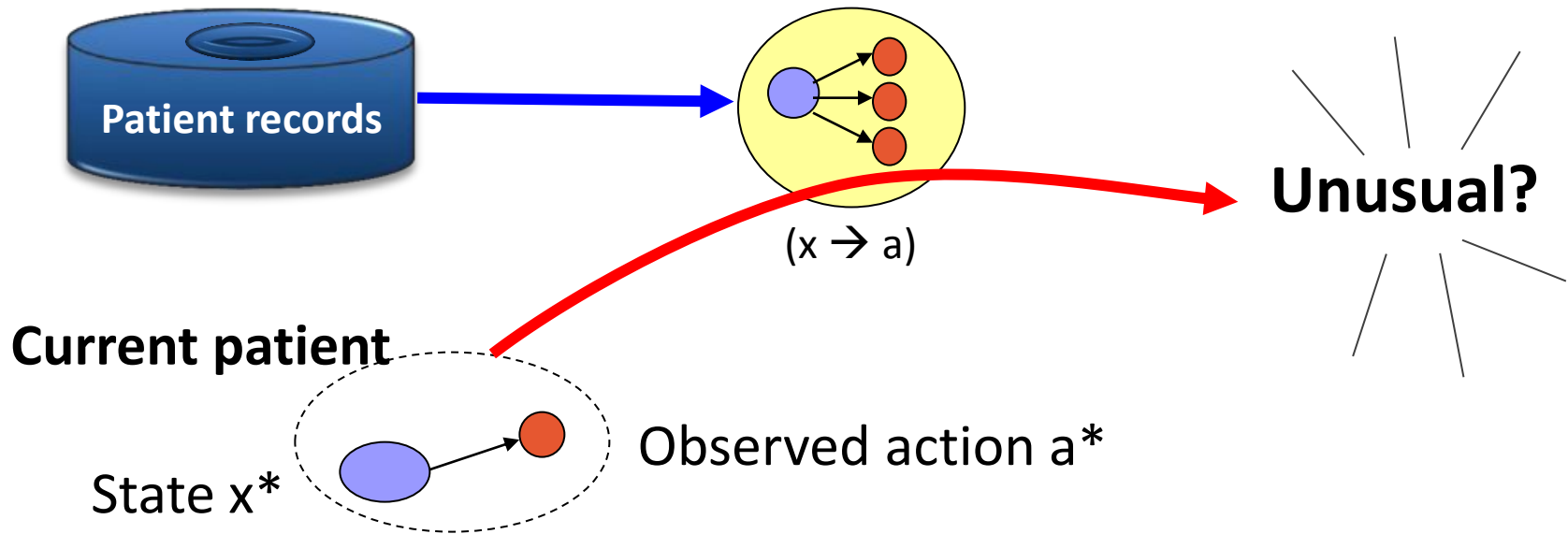
- Identify errors of omission & commission
 - Train on 4,486 cardiac patients; 30,828 episodes



Direction: Learn to Detect Anomalies

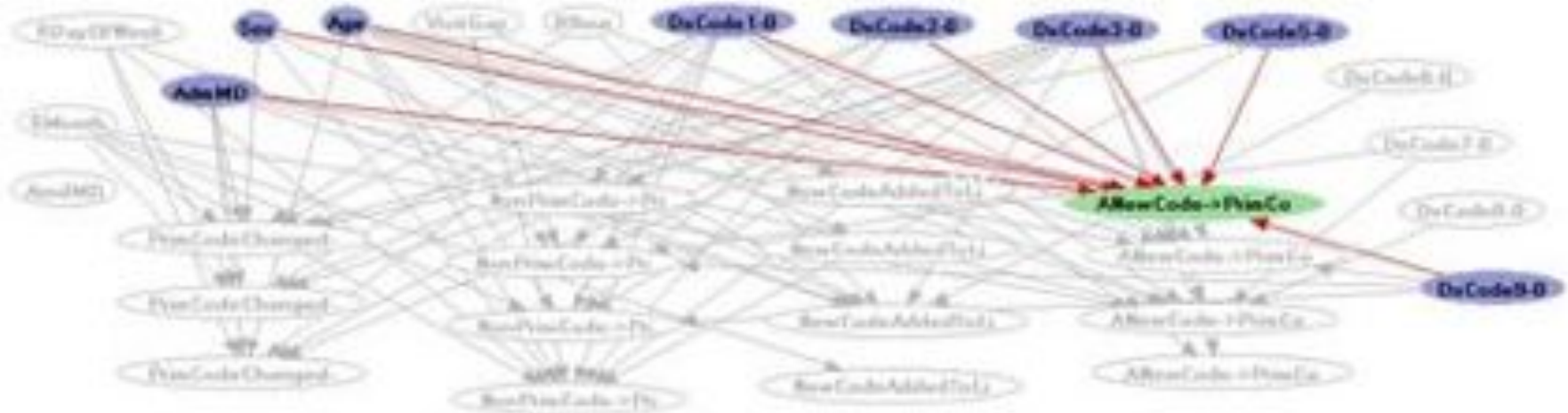
- Identify errors of omission & commission
 - Train on 4,486 cardiac patients; 30,828 episodes

Predictive model:
patient state $x \rightarrow$ actions a



Direction: Forecast Surprises

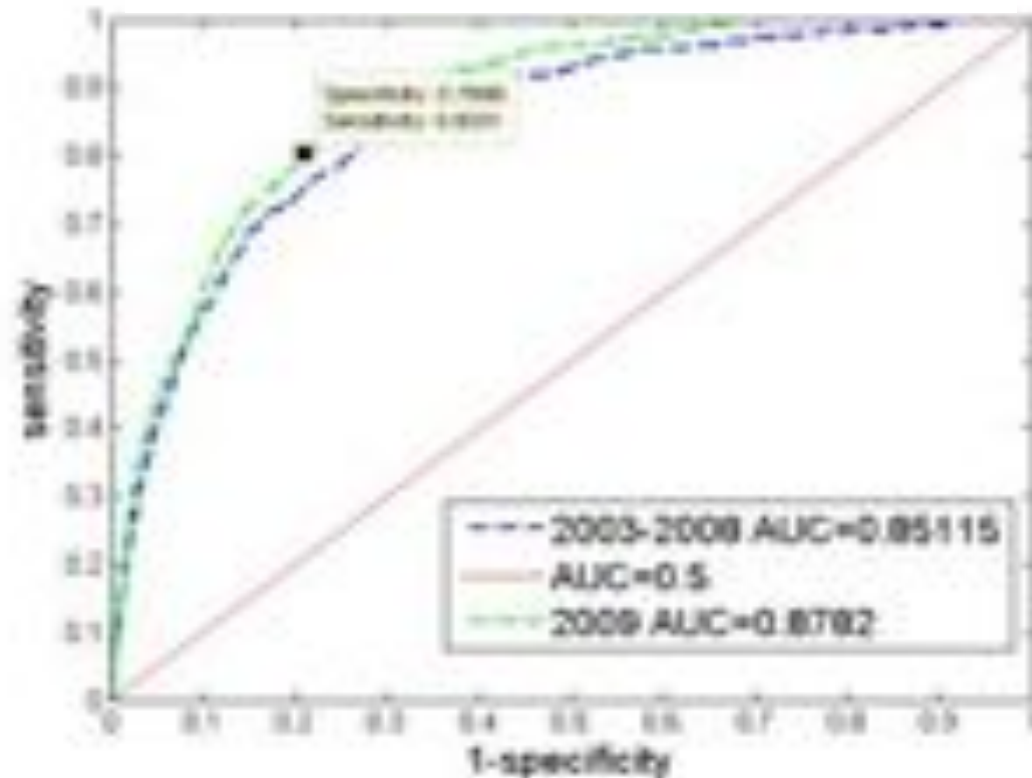
- Infer likelihood that physician will be surprised.
→ Predicts patient will return to ED and be admitted with unforeseen diagnosis.



Direction: Learn to Predict Infection

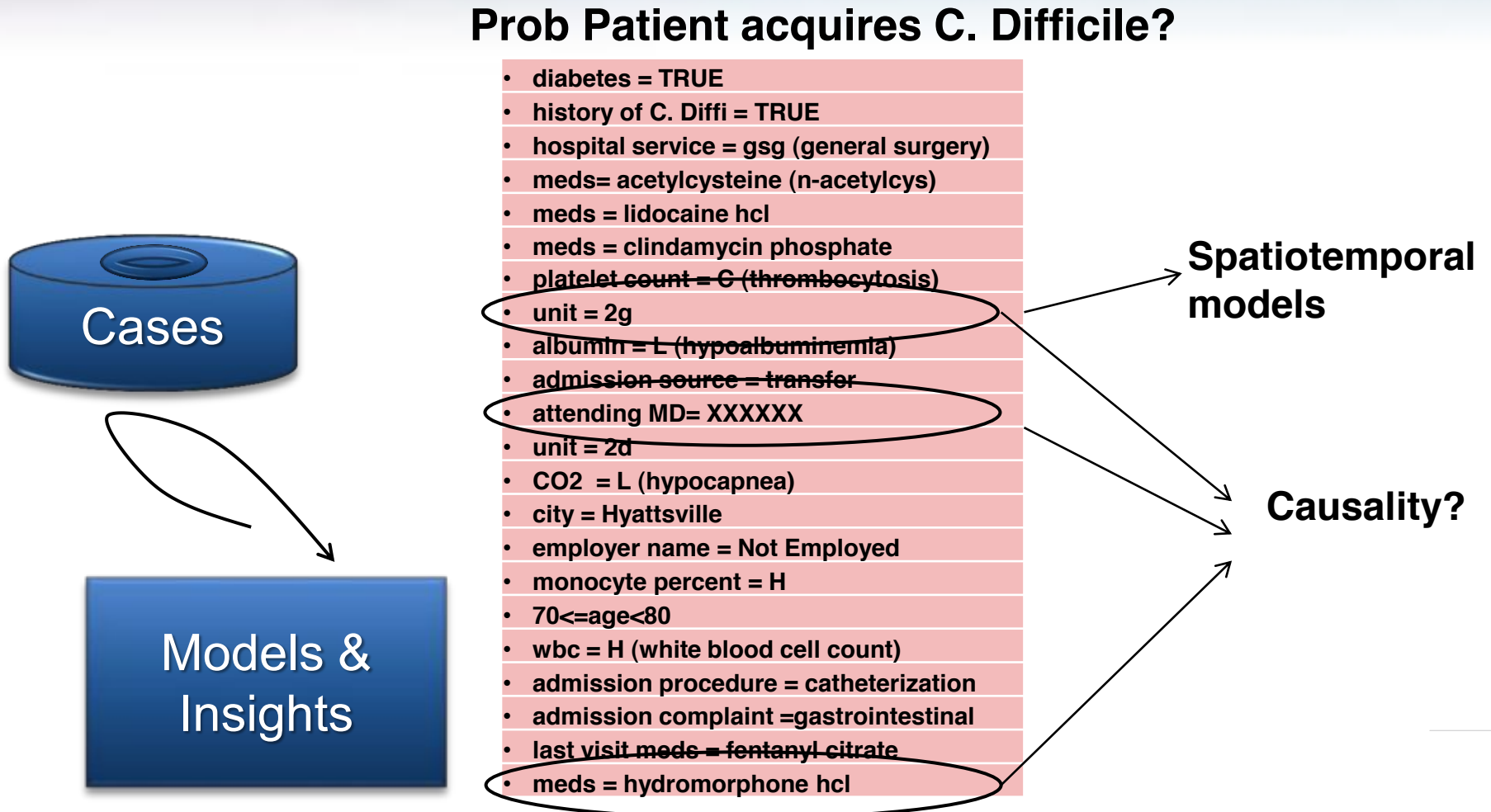
- Healthcare-related infections: 1 in 20 hospital visits
- 5% result in death (top 10 cause of death in US)
- Care costs: ~\$20 billion annually

Predicting MRSA < 48 hrs

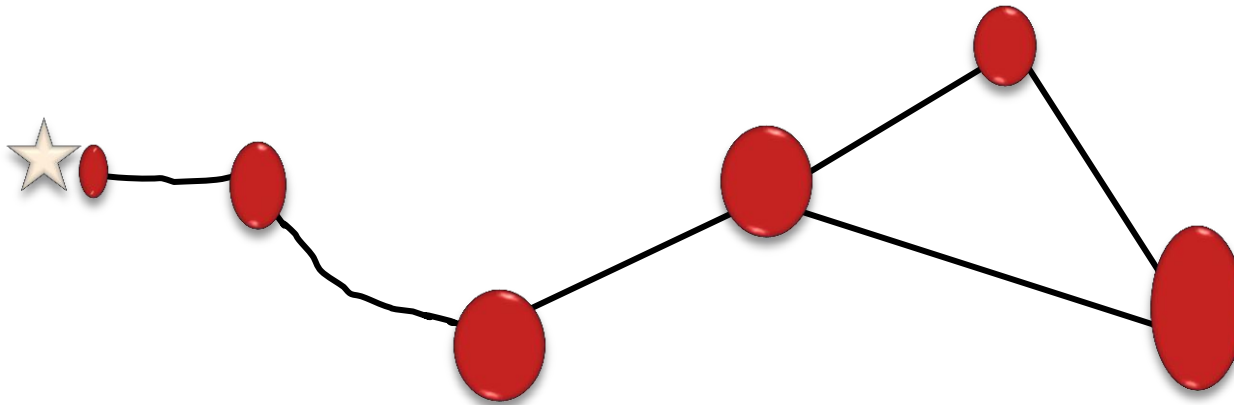
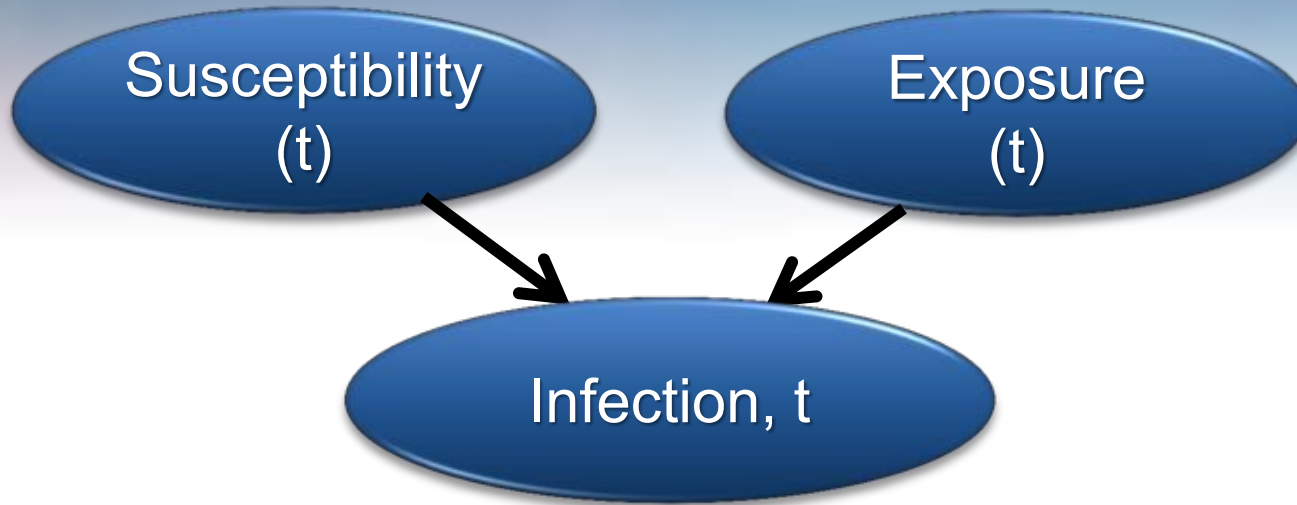


Richer Models & Interventions

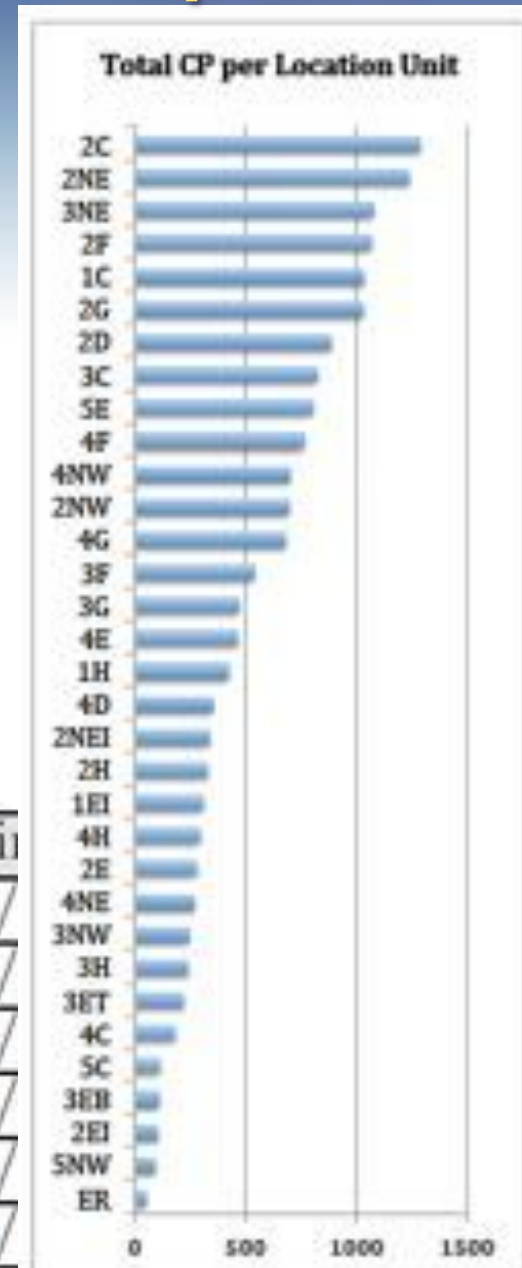
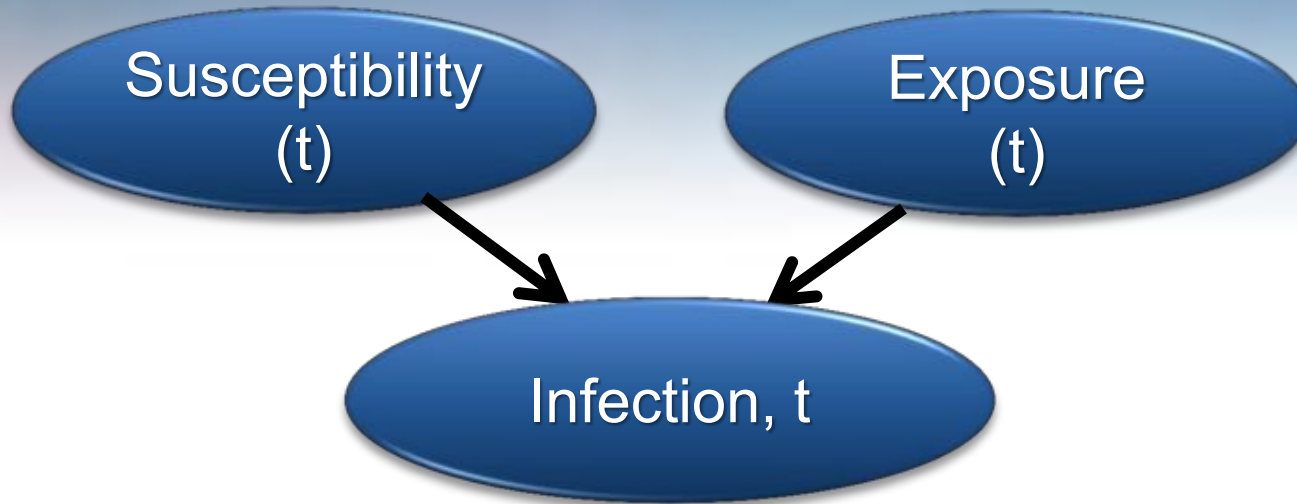
- Insights about deeper mechanisms & causality



Representations of Time and Space



Representations of Time and Space

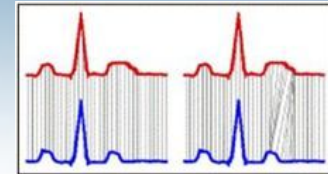


Space & time

Location Unit, Room	Time
Cardiac Cath Unit, 4Axx-P	8/15/
Medicine Patient CU, 4NxxE	8/15/
Main OR, MRxx-P	8/17/
Cardiac Intensive CU, CRxx-P	8/17/
Surgical Patient CU, 4Fxx-B	8/18/
Surgical Patient CU, 4Fxx-A	8/24/

Multiple Advances in Health and CS

- New pattern recognition methods to predict sudden cardiac death from ECG data.
(Syed, et al. 2011)



- Fusion of immunological & clinical data to elucidate links between environmental exposure and pediatric asthma.
(Simpson, et al. 2010)



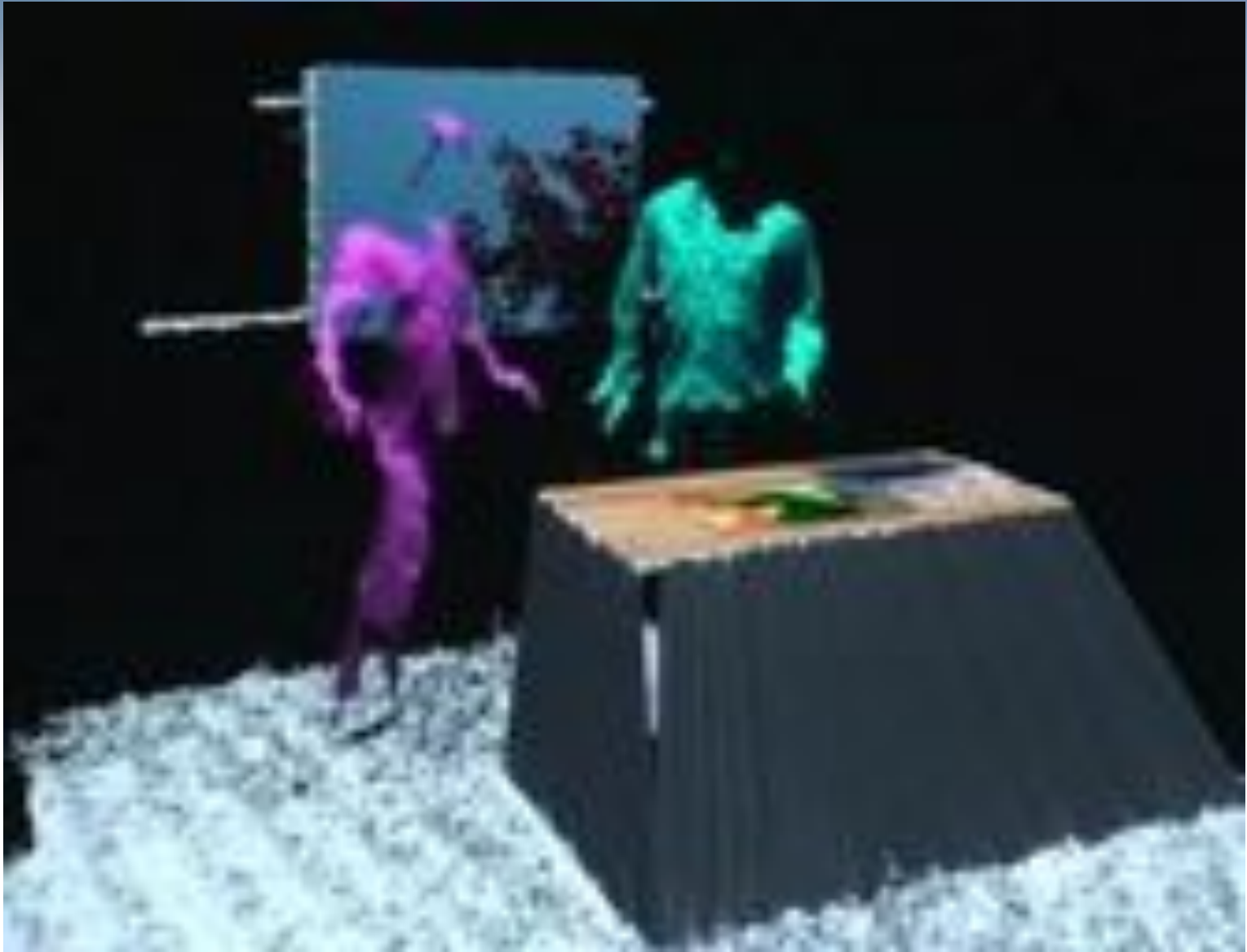
- New image analyses linking histologic features to prognosis in breast cancer.
(Beck, et al. 2011)



- New temporal reasoning to predict NICU outcomes from physiological signals.
(Saria, et al. 2010)



CS Advances and Data Capture in Medicine



Andy Wilson and Hrvoje Benko

CS Advances and Data Capture in Medicine



Research Opportunities Ahead

- Data capture: *workflow, directed vs. ambient, new sources (devices, online activities, etc.)*
- Data sharing and access: *legal, technical*
- Richer models: *time, space, physiology, psychology*
- Causal influences: *from suspicion to cause*
- User modeling: *display, interaction, intention*
- Active learning: *offline & real time*
- Transfer learning: *time & space*
- Fusing genomic, epigenetic, & clinical data

Enabling Evidence-Based Healthcare

- Multiple scientific challenges ahead
- Data capture & availability as key bottleneck
- Criticality of multiple threads of CS research
- Feasibility of enhanced quality at lower cost

On being faithful to the Hippocratic Oath...